Report for Second Quarter FY-2001

1. Submitted by: David Demer, Leader, Advanced Survey Technologies Program, FRD

2. Title: SOLMaR 2000 Middle Trophic Level Oceanographic and Meteorological Investigations

3. Current Status: Completion of Sirena00 Test aboard *Ammiraglio Magnaghi*, 21 August – 5 September 2000. Test description and preliminary analyses documented.

4. Background Information: In response to increasing concern over possible effects of man-made low frequency underwater sounds on marine mammals (e.g., Green, 1994; Frantzis, 1998), NATO's SACLANT Center and the U.S. Office of Naval Research created the Sound, Oceanography, and Living Marine Resources Program (SOLMaR). The primary objective of SOLMaR is to characterize whale behavior in the context of a habitat relatively unperturbed by man-made noise so that subsequent examination of marine mammal response to high intensity sounds may be examined scientifically. Towards this end, the Middle Trophic Level investigations (MTL) of SOLMaR aims to: 1) identify the features of the whales' natural environment that guide their behavior; and most importantly 2) characterize the variability in the environment that normally directs their behavior, dispersion, and abundance.

The first field effort of the MTL (Sirena99) was conducted 2-13 August 1999 aboard the Italian Navy vessel *Ammiraglio Magnaghi* in a productive upwelling region north of Corsica attracting high densities of both sperm and fin whales. The second stage of field experiments (Sirena00) took place in the same area, aboard the same ship, during the period 21 August through 8 September 2000. Concurrent and complementary investigations aboard *Magnaghi* included physical oceanographic, lower trophic level, and marine mammal studies.

The scientific party on *Magnaghi* consisted of eight people: Tony D'Agostino (SACLANT Undersea Research Centre) and Rosella Dimento (Instituto Centrale per la Ricerca Applicata al Mare) maintained and operated all ICRAM's CTD equipment and jointly acted as liaisons between the science party and the ship's officers and crew; Sabastiano Bruno (Tethys) conducted visual surveys of cetaceans; Monica Cantarelli (University of Genova) aided in the cetacean observations and helped process and store the MTL zooplankton samples; and Duncan McGehee (BAE Systems) carried out the lower trophic level studies. Finally, David Demer and Adam Jenkins from the Southwest Fisheries Science Center, La Jolla, CA, USA and Joe Warren from the Woods Hole Oceanographic Institution, Woods Hole, MA, USA took responsibility for the active-acoustical, net capture, and underwater video sampling of large zooplankton, some oceanographic measurements (e.g. dissolved oxygen) and meteorology.

For the Sirena00 Test, the Middle Trophic Level Investigations (MTL) included active-acoustical methods to map the dispersion of krill, fish, and squid; estimate their biomass using echo integration methods (described in Hewitt and Demer, 1993); and determine

their association with predator foraging patterns, water mass boundaries, spatial patterns of primary productivity, and bathymetry (as in Croll et al., 1998; and Fiedler et al., 1998). An underwater digital video system was also used to aid in the validation and observation of acoustic scatterers *in-situ* and to allow observations of predator-prey interactions. Together with the physical oceanographic (sea-surface temperature and dissolved oxygen) and environmental data (wind-speed and direction, air temperature, pressure, and humidity, and solar irradiance), the sampling program provided a four-dimensional (space-time) view of the dispersion, abundance, and dynamics of the trophic level most directly important to the whales in the area.

5. Purpose of Activity: The MTL plan for Sirena00 was to replicate the large-area survey design from Sirena99 (**Fig. 1**) with an extension of the transect lines to the southwest and the northeast, covering more of the deep basin and the shelf (**Fig. 2**). Throughout the first week of the cruise, the weather was fair, hot and humid, with one windstorm on 27 August that caused high seas, temporary cessation of station operations, and appreciable diversion of the tracklines. The latter portion of the survey was again interrupted with two port-calls in La Spezia for provisions, bunkering and exchange of some ship's personnel (31/08), and for refuge from stormy weather (02-03/09). Consequently, stations (St.) 51 to 53 and the associated inter-station transects were not surveyed; planned stations 36, 38, 39, 41, 42, 45, 46, 48, and 49 were not occupied; and long transects number five (St. 36-43) and six (St. 44-50) were surveyed independently of the time of day. Moreover, St. 35 was moved south approximately 2 n.mi. due to a zone temporarily restricted for French military submarine exercises.

Despite these changes in the survey plan, the resultant survey was fairly comprehensive with six of the seven transects acoustically surveyed and six trawl stations sampled with daytime and nighttime replicates and equal shallow- and deep-water coverage. Ultimately, forty-one stations were occupied during Sirena00, nearly all by day and many again by night (**Fig. 2 and Table 1**). At all times, acoustical backscatter data at 38 and 120 kHz and a suite of meteorological data were collected (~1400 n.mi. of trackline effort). Eleven Isaacs-Kidd Midwater Trawls (IKMT) were conducted at six stations and an underwater video system was deployed five times.

6. Description of Accomplishment and Significant Results: Using two Simrad EY500 scientific echosounders (38 single-beam and 120 kHz split-beam), volume backscattering strengths and *in-situ* target strengths were measured continuously while the ship was underway. A 2 m Isaacs-Kidd midwater trawl and an underwater digital video system were deployed to identify the sources of acoustic backscatter. A meteorological station, photosynthetically available radiation sensor (PAR), and a sea-surface temperature probe were used to provide continuous, along-track measurements of meteorological conditions, solar radiation, and sea-surface temperature, respectively. The meteorological data was processed, displayed, and archived with a real-time scientific computing system (Benigni, et al., 1999) and custom Matlab routines.

Relative to the continuous 120 kHz acoustical observations during SIRENA99, the additional frequency (38 kHz) was added to: 1) facilitate daytime observations of deeply residing *Meganyctiphanes norvegica* distributions between 150 and 500 m; 2) thereby provide direct observations of their diel vertical migratory behavior; 3) provide relatively unbiased measurements of *in-situ* target strengths; and 4) make available scattering spectral information to aid in the challenges of acoustic taxa delineation.

A 120 kHz Simrad EY500 echosounder (S.N. 219; Firmware V5.31) was used to survey the distribution of acoustic scatterers in the Ligurian Sea (**Fig. 3**). The primary focus was the euphausiid *M. norvegica*. Data were indexed with time and geographical position using NEMA 0183 telegrams (GPGLL and GPVTG) from the ship's Trimble 4000 GPS, logged using a Hewlett Packard Omnibook 5000CTX notebook computer running Windows95/RMX, and post-processed using SonarData EchoView V2.0097. A Simrad ES120 split-beam transducer (S.N. 27324) was towed to the starboard side of the ship via a boom extending from the starboard bow (**Fig. 4**). The Simrad foil was towed with a 40 m length of 13 conductor 60 Ohm electromechanical cable, fair-leaded through a 16-inch diameter aluminum-alloy snatch-block sheave, and secured to the bulwarks using a kjellums grip attached between two scuppers with shackles and a steel cable. A 75 m length of 13 conductor 60 Ohm deck cable provided connection to the EY500 system housed in the Main Operational Control Room, just aft of the bridge. The tow-fin was deployed by hand. At the typical survey speed of 6 to 7 knots, the transducer was deployed at a depth of approximately 5 m. While the ship was at each station, the echosounder remained active with the tow-fin and 120 kHz transducer hanging vertically at a depth of about 25 m below the sea surface. The 120 kHz echosounder was calibrated prior to the cruise with a 38.1 mm tungsten carbide standard sphere. The sphere calibration experiments were conducted shipboard at the Marina Militare pier in La Spezia.

The 38 kHz system was comprised of a Simrad EY500 Scientific Echosounder (S.N. 616; provided by SWFSC), an IBM ThinkPad 770 notebook computer (S.N. 55163DH; provided by ICRAM), a 7 m 3 conductor 60 Ohm deck cable (SWFSC), and a hull-mounted Atlas 33 kHz single-beam transducer (Model SW6029; *Magnaghi*). The ship's Atlas Deso 20 echosounder was disconnected from the SW6029 and the EY500 was instead connected to the transducer via a junction box located behind the Deso 20 in the Main Operational Control Room. Nominal characteristics of the SW6029 transducer are thought to be: depth = 3.5 m; maximum transmitted power = 4 kW; beamwidth = 8°X6°; acoustic transmission level = 135 dB re 1 ubar/V,1 m; and impedance = 100 Ohms. The system was sub-optimal as the transmit frequency was off resonance for the transducer, the 60 Ohm transceiver and cable impedances were mismatched to the transducer, and the transmit power was relatively low. Because the GPS data were not read by the controlling IBM ThinkPad 770 notebook computer, the 38 kHz acoustical data were necessarily merged with geographical positions in post-processing. Also, the 38 kHz system gain was adjusted relative to the 120 kHz sounder by comparing differences in mean volume backscattering strengths from *M. norvegica* swarms (Sv120-Sv38) to theoretical values derived from a krill scattering model using an empirical krill length-frequency distribution.

During all survey operations, 1 kW acoustic pulses of 1 ms and 3 ms duration were transmitted each second at 120 and 33 kHz, respectively. The transmitted pulses were not synchronized between systems. The echo power levels for each ping were sampled at 25 and 7.5 kHz (~0.03 and 0.1 m resolutions) for time windows corresponding to 250 and 500 m ranges, and compensations were made for spherical spreading and absorption losses. From these data, 700 mean volume backscattering strength values were calculated and stored for each ping (Sv at 0.357 and 0.714 m resolutions).

The Sv data were used to estimate the dispersion and relative abundance of *M. norvegica*. Using EchoView post-processing software, echograms (Sv versus depth and distance) were rendered with ranges from 8 to 255 m at 120 kHz and 6.5 to 503.5 m at 38 kHz. The Sv threshold was set to -90 dB (very roughly equivalent to approximately 0.1 krill per m^3), and portions of the echogram were attributed to echoes from krill and non-krill (bottom return, system noise, and other scatterers).

To generate distribution maps, echo integration methods were employed as detailed in Hewitt and Demer, 1993. Volume backscattering strengths (Sa; m^2/n.mi.^{2}) attributed to *M. norvegica*, were integrated over depths from 8 m to 255 m an interpreted as being proportional to estimates of areal krill density (numbers/m^2 sea-surface; Demer et al., 1999). The resulting Sa values were used to calculate a distribution pattern of relative krill density over the survey area.

To verify species composition and length distributions of krill and small fish, a 2 m Isaacs-Kidd Midwater Trawl (IKMT) was used (**Fig. 5**). This additional net sampling effort was made possible by replacing the proposed contract for an Acoustical Technician by the costs associated with the net sampling, shipping, and travel. The U.S. Antarctic Marine Living Resources Program (AMLR) contributed the labor costs of the Zooplankton Specialist.

A total of 12 zooplankton samples (day- and nighttime tows at St. 11, 19, 26, 34, and 37; nighttime only at St. 43) were acquired using a 2 m IKMT fitted with a 505 µm mesh plankton net and a 16.5 cm diameter PVC cod end. For diel comparison, the IKMT was deployed at a selected station every other day circa noon (1000 GMT) and midnight (2200 GMT). The double-oblique tows to a maximum depth of nominally 200 m were completed in 30 to 40 minutes.

A real-time depth recorder system was readied to monitor the net depth (pressure sensor - Keller Pressure Systems, Inc. Hampton, VA P/N 300DS-340-00995; range 0-995 PSI (0-700m); excitation voltage 9-30VDC; output 4-20 mA). Ultimately, however, this system was not used because *Magnaghi's* primary stern oceanographic winch failed during the first tow. The net was towed from the stern using a mooring capstan and a 600 m of 10 mm diameter Kevlar line. At a nominal towing speed of 2.5 kts through the water, maximum tow depths were estimated from wire-out and angle. Volumes filtered were measured using a calibrated General Oceanic flow meter mounted on the depressor frame

inside of the net mouth opening. Flow volumes were calculated by multiplying flow meter counts by 0.048372 m^3.

All IKMT net samples were examined within two hours of the completed net tow. Biomass was measured as total volume of seawater displaced. Mature euphausiids were identified to species and counted. Remaining zooplankton were identified to general taxonomic groupings and counted. Microzooplankton and phytoplankton fractions were not examined.

Length-frequency data were collected for euphausiids, shrimp and adult fish to the nearest mm. Total lengths (TL) of the euphausiids and shrimp were measured from the tip of the rostrum to the tip of the telson. In samples greater than 100 individuals, TL measurements were made from a random sub sample of approximately 100 individuals. Individuals with TL less than 4mm were assumed to be larval forms and were therefore not included in the length-frequency analysis. Total lengths of adult fish were measured from the tip of mouth to tip of tail.

Representative samples of each species were preserved in a 4% formalin solution and stored in scintillation vials for transportation to SWFSC. ICRAM, the University of Genova, and Tethys Institute saved all remaining samples for further analyses. Depending upon their destination and purpose, the zooplankton were preserved in a 4% formalin solution or frozen in a dewer of liquid nitrogen.

Underwater video observations were also made to provide validation of both the net capture and acoustical information through direct observations of animal taxa and behavior. A Sony DCR TRV-900 3-CCD color digital video camera was housed in a Light and Motion Stingray underwater housing (**Fig. 6**). The camera system had a maximum depth rating of 75m. ICRAM provided a secondary underwater video system that had a black and white VHS imaging capability to a maximum depth of 300 m. A total of five video deployments were made (**Table 1**), including 4 DV and 1 VHS.

While the ship was underway, continuous measurements were made of air temperature, barometric pressure, relative humidity, wind speed and direction, and photosynthetically available radiation and referenced to both time (GMT) and *Magnaghi's* geographic position. A The WeatherPak 2000 meteorological instrument package (**Fig. 7**) was mounted amidships on the forward rail of the flying bridge. Continuous data were logged and displayed in real-time on a Dell Inspiron 7500 notebook computer (S.N. 536-887-89) using a NOAA Scientific Computing System (SCS) software package. PAR data was compromised by saturation of the sensor, ship's motion, and deck lighting. Some breaks in the meteorological data time-series occurred due to multiple port calls and computer malfunction. Nonetheless, the time series was fairly complete and the data were ultimately averaged over 5 min. bins and graphed using custom Matlab routines.

The profiling package consisted of a CTD, with a dissolved oxygen sensor. The CTD was a Seabird Model 19 CTD, and was provided to the project by ICRAM and operated by Rossela Dimento. The profiler was deployed using a starboard side winch on

Magnaghi's helicopter deck. It was lowered at a nominal rate of 0.2 m/s from the surface to 150 m and 1.0 m/s from 150 m to 600 m depth; it was recovered at several meters per second. One profile was made by day at each station (**Fig. 2 and Table 1**), with the exception of station 43, which was occupied only at night. CTD measurements were made twice a second, were logged internally, and downloaded after each cast. Only data from the descents were used. Temperature and salinity were reported directly by the CTD data acquisition program; pressure was converted to depth and oxygen voltage and temperature data were used to calculate percent saturation. SACLANT Centre personnel calibrated the CTD before the cruise.

7. Significance of Accomplishment: Funding for the SOLMaR MTL was provided by the U.S. Department of the Navy / Office of Naval Research / Cognitive, Neural and Biomolecular Science and Technology Division (including travel, shipping, publication(s), supplies, software, transducer deployment apparatus, and electrical components). Cost sharing was provided by the Fisheries Resources and Antarctic Divisions of the SWFSC including salaries and equipment. The Italian Navy generously provided ship-time and the Commanding Officer Mammucari and his crew of *Magnaghi* provided shipboard camaraderie and enthusiastic support of this project.

8. Problems: Ship-to-land communications poor; funding too lean.

9. SWFSC Contact: David Demer; (858) 546-5603; david.demer@noaa.gov

10. References:

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11. Tables

1999 St	2000 St	Depth (m)	Lon	Lat	Activity	D St B	D St E	N St B	N St E	D IKMT B	D IKMT E	N IKMT B	N IKMT E	Video B	Video E
29	1	960	8.6833	44.2033	1	8220413	8220512								
28	2	1100	8.4808	44.0643	1	8220728	8220806								
27	3	520	8.2823	43.9254	1	8221101	8221214	8222211	8222323						
26	4	650	8.0837	43.7864	1	8221413	8221445	8221904	8221944						
25	5	1900	7.8852	43.6475	1	8230409	8230452								
24.3	6	2200	7.6904	43.5174	1	8230658	8230753								
	7	1800	7.4906	43.3797	1	8231010	8231330	8232151	8232232					8232242	8232320
	8	2200	7.2916	43.2417	1	8231519	8231638	8231919	8232038						
	9	2500	7.4744	43.1021	1	8240411	8240448								
	10	2400	7.6728	43.2403	1	8240654	8240745								
	11	2370	7.8720	43.3781	2	8241012	8241242	8242231	8242256	8241210	8241242	8242111	8242141		
24.2	12	2300	8.0721	43.5115	1	8241400	8241445	8241900	8241936						
24.1	13	2500	8.2741	43.6475	1	8250403	8250445								
23	14	2600	8.4767	43.7838	1	8250657	8250731								
22	15	1800	8.6752	43.9254	1	8251008	8251205	8252225	8252346						
21	16	1350	8.8778	44.0618	1	8251420	8251501	8251907	8251941					8252000	8252025
20	17	1000	9.0763	44.2033	1	8260406	8260438								
19	18	650	9.2708	44.0618	1	8260651	8260726								
18	19	850	9.0601	43.9099	2	8260959	8261034	8262228	8262306	8261050	8261119	8262144	8262217		
17	20	1290	8.8616	43.7684	1	8261447	8261521	8261932	8262012						
16	21	2400	8.6671	43.6243	1	8270406	8270524								
15.6	22	2500	8.4774	43.4803	1	8270855	8270935								
15.5	23	2500	8.2842	43.3396	1	8271130	8271247								
15.4	24	2500	8.0910	43.1970	1	8280507	8280542								
	25	2600	7.8973	43.0555	1	8280758	8280840								
	26	2670	7.7045	42.9137	2	8281045	8281209	8282157	8282248	8281045	8281117	8282115	8282146	8282255	8282334
	27	2680	7.8869	42.7821	1	8281407	8281445	8281854	8281934						
	28	2640	8.0827	42.9213	1	8290351	8290438								
15.3	29	2610	8.2795	43.0602	1	8290644	8290729								
15.2	30	2600	8.4727	43.2009	1	8290934	8291055	8292203	8292318					8292236	8292318
15.1	31	2500	8.6671	43.3412	1	8291314	8291400	8291855	8291935						
14	32	2200	8.8656	43.4802	1	8300406	8300446								
13	33	1750	9.0641	43.6191	1	8300654	8300729								
12	34	1200	9.2627	43.7581	2	8300948	8301120	8302104	8302131	8301045	8301120	8302005	8302038		
11		450	9.4571	43.8945	0										
	35	680	9.3873	43.8466	1	8301256	8301335	8301825	8301904						
10	36	500	9.4571	43.6140	0										
9	37	750	9.2667	43.4802	2	9011607	9011650			9011407	9011450	9012100	9012132		
8	38	1850	9.0722	43.3387	0										
7	39	2150	8.8737	43.1997	0										
6	40	2550	8.6793	43.0582	1	9041644	9041744								
	41	2600	8.4836	42.9185	0										
	42	2600	8.2888	42.7785	0										
	43	2650	8.0949	42.6382	2	9042308	9042352					9050057	9050129	9050031	9050040
	44	2650	8.2895	42.4963	1	9050355	9050436								
	45	2000	8.4839	42.6359	0										
5	46	1300	8.6793	42.7751	0										
4	47	1750	8.8737	42.9166	1	9051025	9051102								
3	48	1790	9.0722	43.0556	0										
2	49	400	9.2708	43.1945	0										
1	50	370	9.4652	43.3361	1	9051641	9051715								
	51	76	9.4630	43.0519	0										
	52	90	9.2639	42.9130	0										
	53	200	9.0650	42.7740	0										

Table 1. Station numbers from Sirena99; corresponding numbers from Sirena00; apx. Bottom depths at station positions (Lat, Lon); 2000 activity code (0=no station; 1=IKMT tow(s); and 2=IKMT and underwater video); and beginning (B) and end (E) times for the daytime (D) and nighttime (N) IKMT tows and video deployments.

12. Figures

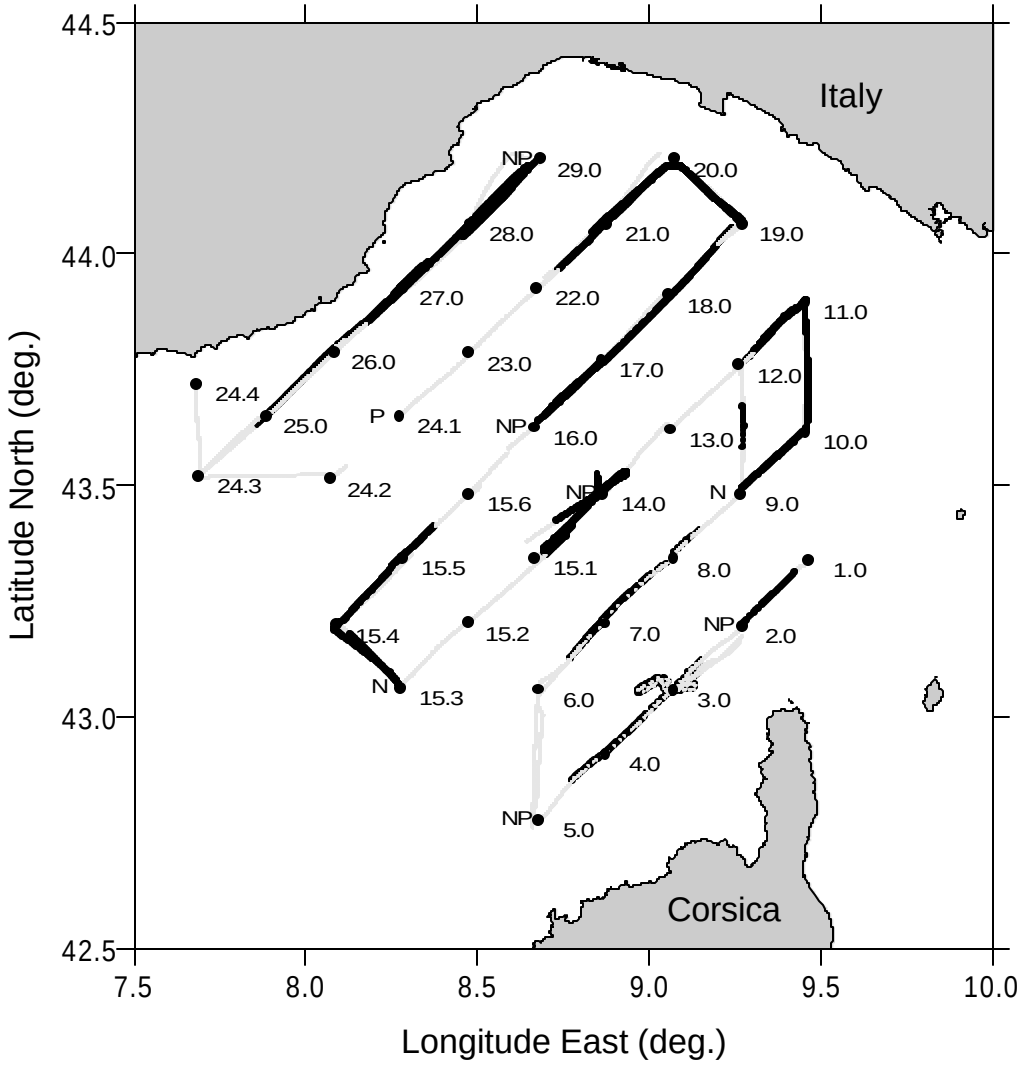

Fig. 1: Trackline for Italian Naval Hydrographic Vessel Ammiraglio Magnaghi during SIRENA99, 2-13 August, 1999. Thin transects depict the daytime active-acoustical survey (0600-1959 Local) and bold transects indicate the Day- and nighttime active-acoustical survey (2000-0559 Local). CTD and TAPS were deployed at all daytime stations; additionally CTD and TAPS were deployed at night at some stations (N). The plankton net was towed at stations marked P.

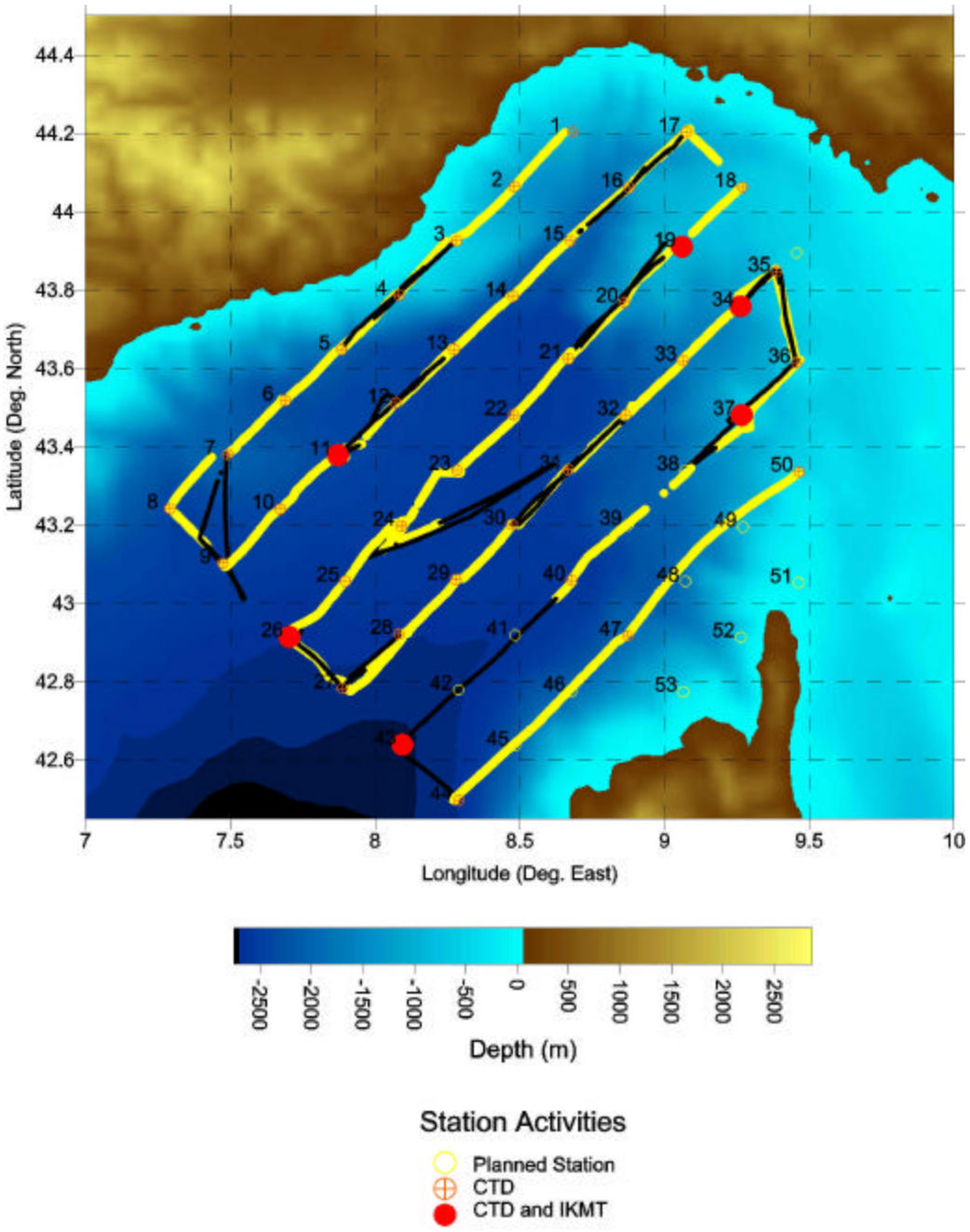

Fig. 2: Trackline for Italian Naval Hydrographic Vessel *Ammiraglio Magnaghi* during SIRENA00, 21 August to 8 September 2000. Yellow transects depict the daytime active-acoustical survey (0400-1759 GMT) and black transects indicate the day- and nighttime active-acoustical survey (1800-0359 GMT). An exception is the effort between stations 40 and 44, which was conducted at nighttime only. The CTD with oxygen sensor was deployed at nearly all daytime stations (except 43; nighttime only), and again at night at some stations. The Isaacs-Kidd Midwater trawl was towed at six stations.

Fig. 3: Two Simrad EY500 scientific echosounders. The 120 kHz echosounder (left) was connected to a 120 kHz split-beam transducer that was deployed from a depressor-style towed-body. The 38 kHz echosounder (right) was connected to a Krupps Atlas Deso single-beam 33 kHz transducer mounted in the ship's hull.

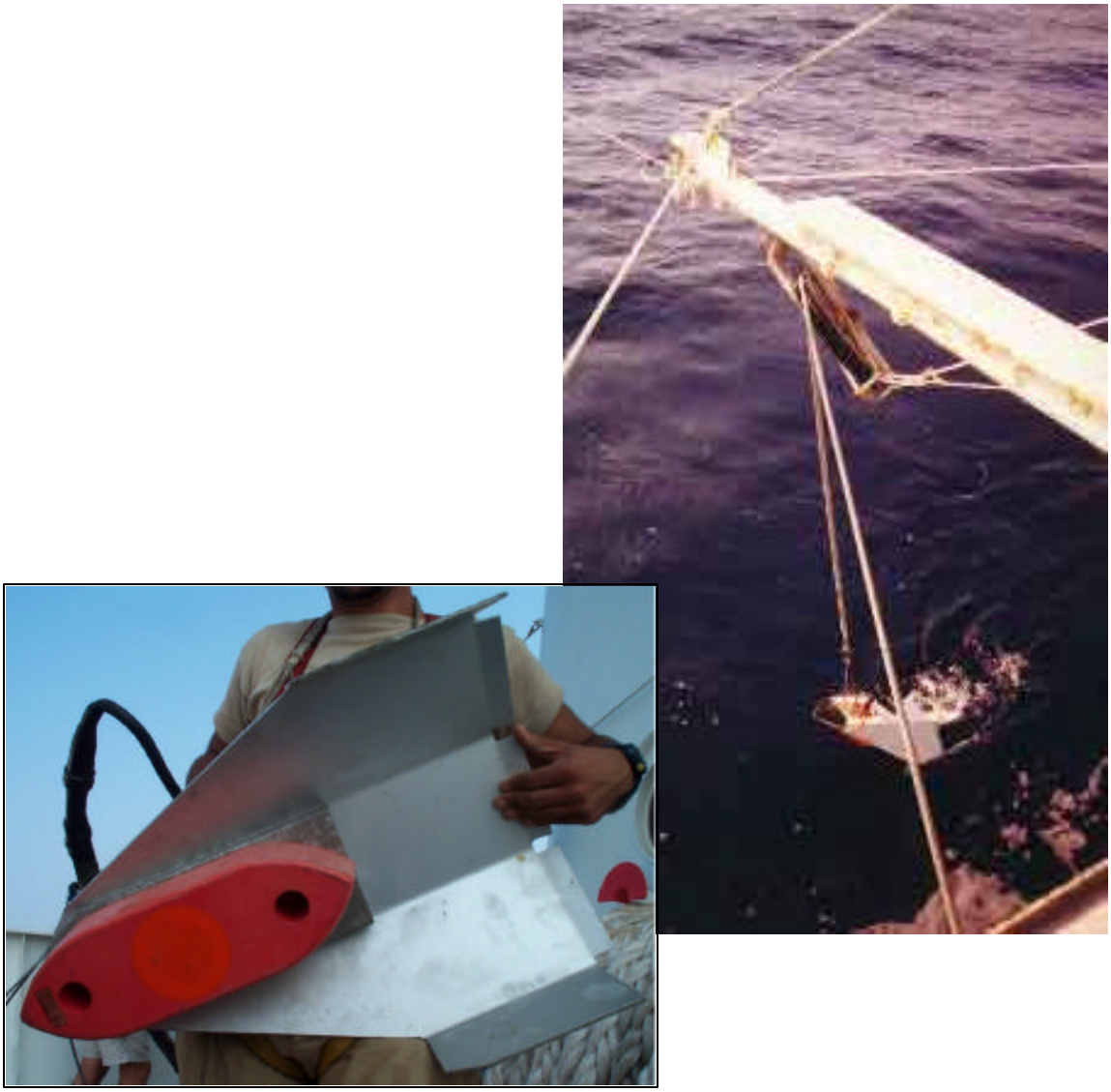

Fig. 4: Simrad 120 kHz split-beam transducer (ES120-7F) and Simrad depressor-style towed-body deployment apparatus. The transducer was deployed from a boom on the starboard bow using a 13 conductor electromechanical towing cable.

Fig. 5: A 2 m Isaacs-Kidd Midwater trawl with 505 um mesh net and General Oceanics flow meter. The net was deployed from the stern of *Magnaghi* to a standard depth of 200m using a 600m Kevlar line and the hydraulic mooring capstan.

Fig. 6: Underwater video apparatus including a Sony DCR TRV900 3-CCD digital video camera and a Light and Motion Stingray housing with lights. The maximum deployment depth was 75 m.

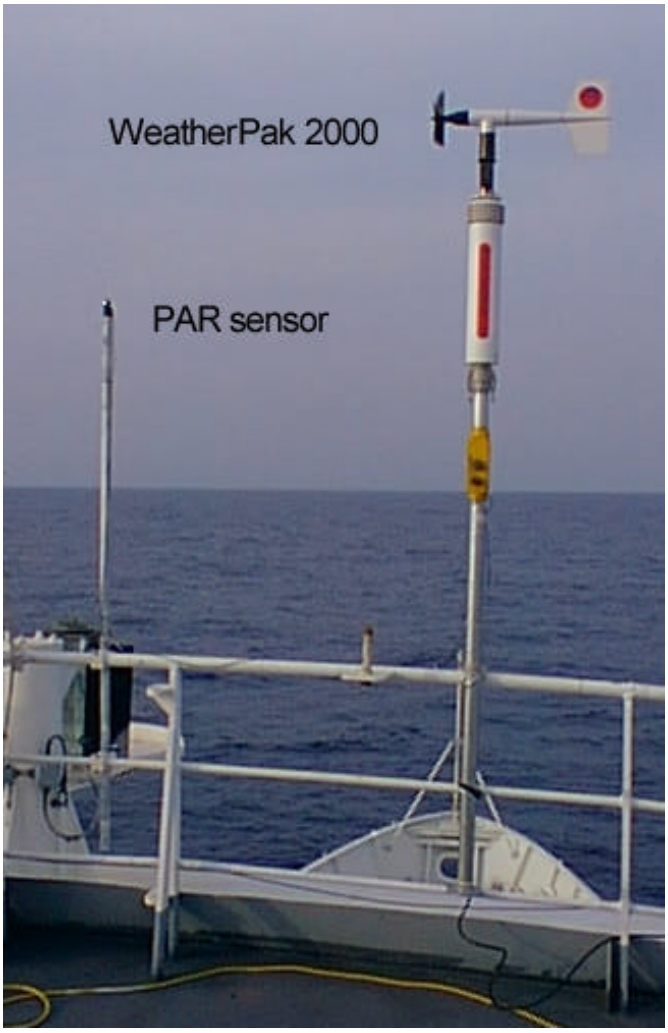

Fig. 7: Meteorological data systems including the Coastal Environmental Systems WeatherPak 2000 with photosynthetically available radiation sensor (right) and the ship's meteorological sensors (top left). Data were logged and processed with NOAA's Shipboard Computing System (lower left) and custom Matlab routines.